The Concentration of Zn, Fe, Mn, Cu and Se in Fiber Fractions of Legumes in Indonesia

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Abstract. This study was carried out to evaluate concentration of micro minerals (Zn, Fe, Mn, Cu and Se) of forages and their distribution in fiber fraction (neutral detergent fiber/NDF and acid detergent fiber/ADF) in West Sumatra during dry and rainy seasons. Four species of common legume namely *Leucaena leucocephala*, *Centrocema pubescens*, *Calopogonium mucunoides* and *Acacia mangium* were collected at native pasture during rainy and dry seasons. The results showed that micro minerals concentration of forages and their distribution in fiber fraction varied among species and season. In general, concentration of micro minerals was slightly higher in rainy season compared to dry season either in legumes forages. Data on legume forages showed that 75% of legumes were deficient in Zn and Mn, 62.5 % deficient in Cu and 50 % deficient in Se. There was no species of legume deficient in Fe. Distribution of micro minerals in NDF and ADF were also significantly affected by species and season and depends on the kinds of element measured. Generally, micro minerals were associated in fiber fractions and it yield much higher during dry season compared to rainy season. Iron (Fe) and selenium (Se) in forages were the highest elements associated in NDF and ADF, while the lowest was found in Copper (Cu).

Keywords: Seasons, forages, micro mineral distribution, fiber fraction

Introduction

Most of grazing livestock in tropical countries including Indonesia fulfil their mineral requirements usually only from the forages consumed. Since the forages are frequently deficient or excess in various minerals, the animals may have sub clinical deficiencies or chronic toxicities. Aside from the above mentioned problem, the use of minerals by animals was constrained by their bioavailability. Some minerals in the forages are associated with other compounds or trapped in the undigested nutrient fractions resulting in slowly release or making these unavailable for use. Therefore, in assessing minerals requirement of the animals, both the amount of mineral in forages and their bioavailability need to be considered. The mineral content can be determined chemically while bioavailability is much more difficult to be estimated. The bioavailability of the minerals can be affected by their location in forage structure. Emanuele and Staples (1990) reported that minerals associated with the plant cell wall have lower bioavailability or require a longer fermentation time for maximal release. There was no information available concerning mineral distribution and their bioavailability of forages in South Sumatra in relation to different seasons. The aim of this study was to evaluate micro minerals concentration of the forages and their distribution in NDF and ADF during rainy and dry seasons.

Materials and Methods

Study area and collection of forages samples

The study was conducted in West Sumatra province–Indonesia. Four species of common forages namely *Leucaena leucocephala*, *Centrocema pubescens*, *Calopogonium mucunoides* and *Acacia mangium* were collected at native pasture during rainy and dry seasons. The Province of West Sumatra lies between $0^{o}30$ North - $3^{o}30$ South and between $98^{o}36$ to $101^{o}53$ East with the land area of about 49,778 km^2. There are two seasons in the provinces, the dry season begins from June to September and rainy season relatively occurs from October to May. The average of rainfall in East Sumatra is about 2,289 mm per year. The daily temperature of West Sumatra varies from

24-32°C and 73-84% humidity. The land of West Sumatra consists almost 11 kinds of soil; Organosol, Litosol, Alluvial, Grey Hidromorf, Klei Humus, Regosol, Andosol, Rendzina, Latosol, Lateritik and Podzolik.

Determination of micro mineral distribution

Micro minerals (Zn, Fe, Mn and Cu) concentrations in the forages samples and fiber fractions were analyzed using inductively coupled plasma emission spectrometer (SPS7700, Seiko Instruments Inc., Chiba, Japan) after digesting with nitric acid. Selenium (Se) was analyzed through the fluorometric detection of the 2, 3 Diamino-naphthalene (DAN) according to the procedure of Watkinson (1966). The spectrofluoro photometer used was RF- 1500 (Shimandzu Co).

Statistical analysis

Data on the chemical composition, mineral content, *in vitro* digestibility, *in vitro* gas production and metabolizable energy content were analyzed using General Linear Model (GLM) procedure for computations of means and standard errors, according to SAS/Start View (1999). The mean comparison between the species of forages and seasons were compared using probability of differences. The following statistical model was used in the analysis: $Y_{ijk} = \mu + S_i + F_k + e_{ik}$ (Where: Y_{ik}=dependent variable (general observation); μ=the overall mean; S_i= effect of the i^{th} season (i=dry and rainy season); F_k=effect of k^{th} species; e_{ik}=error term).

Results and discussion

Micro mineral concentration of forages

There was significant difference ($P<0.05$) in micro mineral concentration of legume forages within species and seasons (Table 1). Data on legume showed that concentration of micro mineral in rainy season was relatively higher than in dry season. The highest concentrations of Zn, Cu and Se were found in *C. pubescens* during rainy season (40.2, 16.6 and 0.405 mg/kg), while the highest concentrations of Fe and Mn were found in *C. mucunoides* (589.6 mg Fe/kg in dry season and 49.2 mg Mn/kg in rainy season). The lowest concentrations of Zn and Cu were observed in *A. mangium* during dry season (25.0 and 3.8 mg/kg), Fe and Mn in *L. leucocephala* (138.8 and 22.2 mg/kg) and the lowest Se concentration was noted in *C. mucunoides* (0.071 mg/kg) during dry season. The results also show that 75% of the observed legumes were deficient in Zn and Mn, and 62.5% deficient in Cu and 50% deficient in Se. Concentrations of the micro elements in legumes in the present study were within the ranges for the tropical forages as reported by several researchers (Evitayani et al., 2004; Fujihara et al., 1992; Prabowo et al., 1991 and Serra et al., 1994). The mean legume forages (31.1mg/kg DM) were almost similar with the study of Minson (1990) which obtained value of 36 mg Zn/kg DM in pasture. The mean Fe and Cu concentrations were significantly higher ($P<0.01$) in legumes (287.1; 10.4 mg/kg DM). This finding was in agreement with the study of Minson (1990) and Miller (1984) who reported that concentration of some micro minerals are normally higher in legume than in tropical forages. The mean of Cu concentration was slightly higher than the requirement for sheep (7.0 mg/kg DM). Decreasing Cu concentration of legume forages may occur with advancing maturity, climatic and seasonal changes (Spears, 1994). Between the seasons, Se concentration of legume forages slightly higher in rainy season than in dry season and are higher than required in the feed for ruminants (0.2 mg/kg DM) as recommended by NRC (1984).

According to Underwood and Suttle (1999a and 1999b), increasing soil water can have a negative influence on soil trace mineral especially Se. In contrast, the tendency for the lower mineral content of legume forages in dry season is probably a reflection of the influence of rainfall. Several studies (Evitayani et al., 2004; Fujihara et al., 1992; Master et al., 1992; Prabowo et al., 1991) have reported that seasonal fluctuations in micro mineral composition persisted in grazing pasture. Results of the present study also showed that Fe (rainy and dry seasons) of forages were not deficient. However, Zn was deficient in *A. mangium*; Mn was deficient in *C. pubescens, L. leucocephala* and *A. mangium*; and *A. mangium*, respectively. While in dry season, Zn

Table 1. Micro mineral concentration of legume (mg/kg DM)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Critical level*		33	50	40	11	0.20
Toxic level		750	500	1000	25	2.00
Legumes species	RDS	ns	***	**	*	*
C. pubescens	Rainy	40.20	297.40	37.30	16.60	0.41
	Dry	27.90	282.60	29.00	15.00	0.30
	RDS	**	**	**	ns	*
C. mucunoides	Rainy	35.80	525.00	49.20	9.30	0.08
	Dry	30.00	589.60	38.40	8.80	0.07
	RDS	ns	***	**	*	ns
L. leucocephala	Rainy	32.90	157.20	27.10	11.60	0.13
	Dry	26.20	138.80	22.20	8.60	0.12
	RDS	**	**	*	*	ns
A. mangium	Rainy	30.60	159.40	38.90	9.80	0.20
	Dry	25.00	147.00	27.50	3.80	0.11
	RDS	*	**	**	**	*
Mean of legumes	Overall	31.1±1.1	287.1±0.6	33.7±2.6	10.4±1.3	0.48±0.1
Deficiency (%)	Overall	75.00	0.00	75.00	62.50	50.00
Sig. of effect	Species	***	***	***	***	***
	Season	ns	*	*	ns	ns
	Spe. X Sea.	**	ns	*	ns	ns

RDS: Season effect in rainy and dry seasons. *** : P<0.001; ** : P<0.01; * : P<0.05 and ns : non-significant

was deficient in four species except for Mn was deficient in *C. pubescens, L. leucocephala* and *A. mangium*; Cu was deficient in four forage species except for *C. pubescens* and Se was deficient in *C. mucunoides*, respectively. However, deficiency of Zn in legume was 100%; deficiency of Cu was 62.5% in legume; deficiency of Mn was 75% in legume and deficiency of Se was 50% in legume. McDowell (1976 and 1985) reported that of Zn, Cu, Mn and Se were the most severe mineral limitation to grazing livestock in tropical countries especially in Indonesia; while individual evaluation of samples based on Fe requirements of 50 mg/kg DM indicated that none of legume forages were deficient in Fe. The zero incidence of iron (Fe) deficiency in legume forages in both rainy and dry seasons was also obtained by Prabowo et al. (1991).

Mineral proportion of forages in Neutral Detergent Fiber (NDF)

The micro mineral proportion of legume forages in NDF is shown in Table 2. Both seasons and species significantly (P<0.05) affected Zn, Fe, Mn, Cu and Se. In rainy season, the highest proportion of Zn in NDF of legume forages showed that the lowest proportion of Zn, Fe, Mn, Cu and Se in NDF during rainy season were 5.7% in *C. pubescens*, 32.0% in *C. mucunoides*, 3.2% in *C. pubescens*, 10.3% in *C. pubescens* and 9.2% in *C. mucunoides* while the highest proportion were 42.0% (*C. Mucunoides*), 81.8% (*L. leucocephala*), 30.9% (*L. leucocephala*), 66.0 % (*A. mangium*) and 78.1% (*L. leucocephala*), respectively. The proportion of Zn, Fe, Mn, Cu and Se in legume tended to increase during dry season, ranged from 7.0 (*C. pubescens*) to 45.0% (*C. mucunoides*) for Zn, 25.0 (*C. mucunoides*) to 75.3% (*L. leucocephala*) for Fe, 6.7 (*C. pubescens*) to 36.1% (*L. leucocephala*) for Mn, 9.0 (*C. pubescens*) to 67.2% (*A. mangium*) and from 11.0 (*C. mucunoides*) to 35.2% (*A. mangium*), respectively. The great variation of micro mineral proportion in NDF could be reflecting the mineral affinity to the cell wall that affected their bioavailability and cause deficiency symptoms to the grazing animals. The proportion of Zn and Fe in NDF of this study almost similar with the data obtained by Kincaid and Cronrath (1983) and Ibrahim et al. (1990) who reported 31, 77 and 45% of total Zn and Fe were located in NDF fraction of lucerne hay. The mean in legume the proportion of Zn and Fe was 51.6 and 58.8%, respectively. In contrast, Serra et al. (1996) reported that the mean proportion of Zn and Fe in NDF of forages were 2.9 and 81.3%,

respectively. Between micro mineral elements, Mn was lowest proportion in NDF reflecting the low affinity to the cell wall (Serra et al., 1996). The relative higher of micro mineral proportion in NDF during dry season could be due to fluctuation of rainfall and differences of these elements in affinity to the cell wall, that could affect the solubility and hence deficiency symptom to the grazing animals (Ibrahim et al., 1990; Kincaid and Cronrath, 1983; Ibrahim et al., 1990 and Serra et al., 1996).

Mineral proportion of legume in ADF

The micro mineral proportion of forages in ADF was significantly (P<0.05) different in both seasons and species (Table 3). The proportion of micro mineral in ADF of legumes, the proportion of micro mineral in ADF during rainy season varied from 1.7 (*C. pubescens*) to 4.2 % (*C. mucunoides*) for Zn, 16.9 (*C. mucunoides*) to 55.9% (*L. leucocephala*) for Fe, 4.1 (*C. pubescens*) to 29.3% (*C. mucunoides*) for Mn, 1.4 (*C. pubescens*) to 3.0% (*C. mucunoides*) for Cu 8.4 (*C. mucunoides*) to 34.8% (*L. leucocepahala*) for Se, respectively. While in dry season, the lowest proportion of Zn, Fe, Mn, Cu and Se elements were 1.2% (*C. pubescens*), 35.9% (*L. leucocephala*), 5.2% (*L. leucocephala*), 1.2% (*A. mangium*) and 10.7% (*C. mucunoides*) and the highest of Zn, Fe, Mn, Cu and Se elements were found in *L. leucocephala* (7.4%), *C. pubescens* (48.2%), *C. mucunoides* (30.8%), *L. leucocephala* (5.1%) and *L. leucocephala* (59.9 %), respectively.

The wide variation of micro mineral proportion in ADF residue in the present study shows that the rate of affinity of these elements with lingo cellulosic materials differed each other (Edwards et al., 1977; Ibrahim et al., 1990; Kincaid and Cronrath, 1983 and Mc Dowell, 1985). The average of Zn proportion in ADF of legume (3.9%) in the present study was similar with the result of Ibrahim et al. (1990) who indicated that 3% of Zn remained in ADF fraction of *Gliricidia*. The highest proportion elements in ADF were found in Fe and Se (35.3 and 34.4%) for legume species. Similar result was reported Ibrahim et al. (1990) and Serra et al. (1990). In general, legume contained lowest proportion of micro mineral in NDF that legume reflecting a higher trapped of the elements into ligno-cellulose.

Table 2. Micro mineral proportion in NDF of legume (%)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Legumes species	RDS	*	***	*	*	*
C. pubescens	Rainy	5.70	60.10	3.20	10.30	15.30
	Dry	7.00	75.20	6.70	9.10	13.40
	RDS	*	**	*	Ns	*
C. mucunoides	Rainy	42.00	32.00	9.40	11.50	9.20
	Dry	45.20	25.20	11.20	12.80	11.00
	RDS	Ns	**	**	Ns	*
L. leucocephala	Rainy	20.30	75.30	30.90	16.80	78.10
	Dry	18.50	81.20	36.10	19.20	84.80
	RDS	Ns	**	Ns	**	**
A. mangium	Rainy	36.10	61.30	11.90	66.00	33.60
	Dry	42.00	60.10	10.19	67.20	35.20
	RDS	**	Ns	Ns	Ns	Ns
Mean of legumes	Overall	27.1±0.6	58.8±0.7	14.6±2.6	26.6±0.8	35.1±1.0
Sig. of effect	Species	***	***	***	***	***
	Season	ns	*	*	ns	ns
	Spe. X Sea.	**	ns	*	ns	ns

RDS : Season effect in rainy and dry seasons. *** : P<0.001; ** : P<0.01; * : P<0.05 and ns : non significant

Table 3. Micro mineral proportion in ADF of legume (%)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Legumes species	RDS	*	**	ns	ns	*
C. pubescens	Rainy	1.65	37.37	4.08	1.41	30.45
	Dry	1.24	48.20	7.34	2.05	29.86
	RDS	*	**	**	ns	ns
C. mucunoides	Rainy	4.12	16.90	29.34	3.02	8.40
	Dry	6.55	40.60	30.77	4.11	10.67
	RDS	*	***	*	ns	**
L. leucocephala	Rainy	2.28	55.90	8.40	2.75	34.80
	Dry	7.35	35.90	5.17	5.05	59.87
	RDS	*	***	*	*	***
A. mangium	Rainy	2.81	31.34	9.16	2.05	25.98
	Dry	5.23	42.30	13.32	1.15	30.65
	RDS	*	**	*	Ns	*
Mean of legumes	Overall	3.9±1.6	38.6±3.8	13.4±3.7	2.7±0.5	34.4±0.5
Sig. of effect	Species	**	**	***	**	***
	Season	***	ns	*	ns	***
	Spe. X Sea.	**	**	ns	ns	***

RDS:Season effect in rainy and dry seasons. *** : P<0.001 ; ** : P<0.01; * : P<0.05 and ns : non significant

Conclusions

From the above results, it could be concluded that nutritive value of forages in West Sumatra assessed by distribution of micro mineral either in intact forages or in fiber fractions (NDF and ADF) greatly varied between species and seasons. In rainy season, the concentration of Fe and Se was above the requirement of the ruminants, while in dry season some of the forages were deficient for these elements. A high content of cell wall constituent (NDF and ADF) has been associated by attachment more minerals into the cell wall. However, most of the mineral elements were found in the cell contents and should be available to the ruminants.

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